

# Artificial Intelligence: Powering Human Spaceflight Exploration of the Moon and Mars

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**NASA Ames Research Center**

## Where are we going?

- The Moon and Mars

## Mission Operations

- Communications Time Delay

## Artificial Intelligence Technology

- Planning
- Plan Execution
- Fault Management

## Making it Happen!

- Helping Astronauts
- Making Spacecraft Smart
- ...and More!





A photograph of the Orion spacecraft in lunar orbit, showing the Earth's horizon in the background.

Distance:  
238,000 Miles

A photograph of the lunar surface showing the shadow of the Apollo 16 Lunar Module.

Time Delay:  
1.2 seconds one way

A 3x5 grid of 15 black and white images showing the movement of an asteroid across the field of view. The asteroid appears as a small, bright, elongated object that shifts its position from the top-left towards the bottom-right across the sequence of frames.

Distance:  
3,600,000 Miles

(285263) 1998 QE2

Time Delay:  
14 seconds one way



A black and white photograph of the asteroid Itokawa, showing its irregular, rocky surface with numerous craters and a dark shadow cast across it.

Distance:  
26,100,000 Miles

Itokawa, 2007

Time Delay:  
2.3 minutes one way

A black and white photograph of the Mars surface, showing a rocky terrain with a large, dark, shadowed area in the foreground and a bright, hazy horizon in the background. The text is overlaid on the image.

Distance:  
34,800,000 Miles

Time Delay:  
2.5 minutes one way  
(minimum!)



A large, detailed image of the planet Mars, showing its reddish-orange surface, polar ice caps, and various craters and geological features. The text is overlaid on the image.

Distance:  
250,000,000 Miles

Time Delay:  
24 minutes one way  
(maximum!)

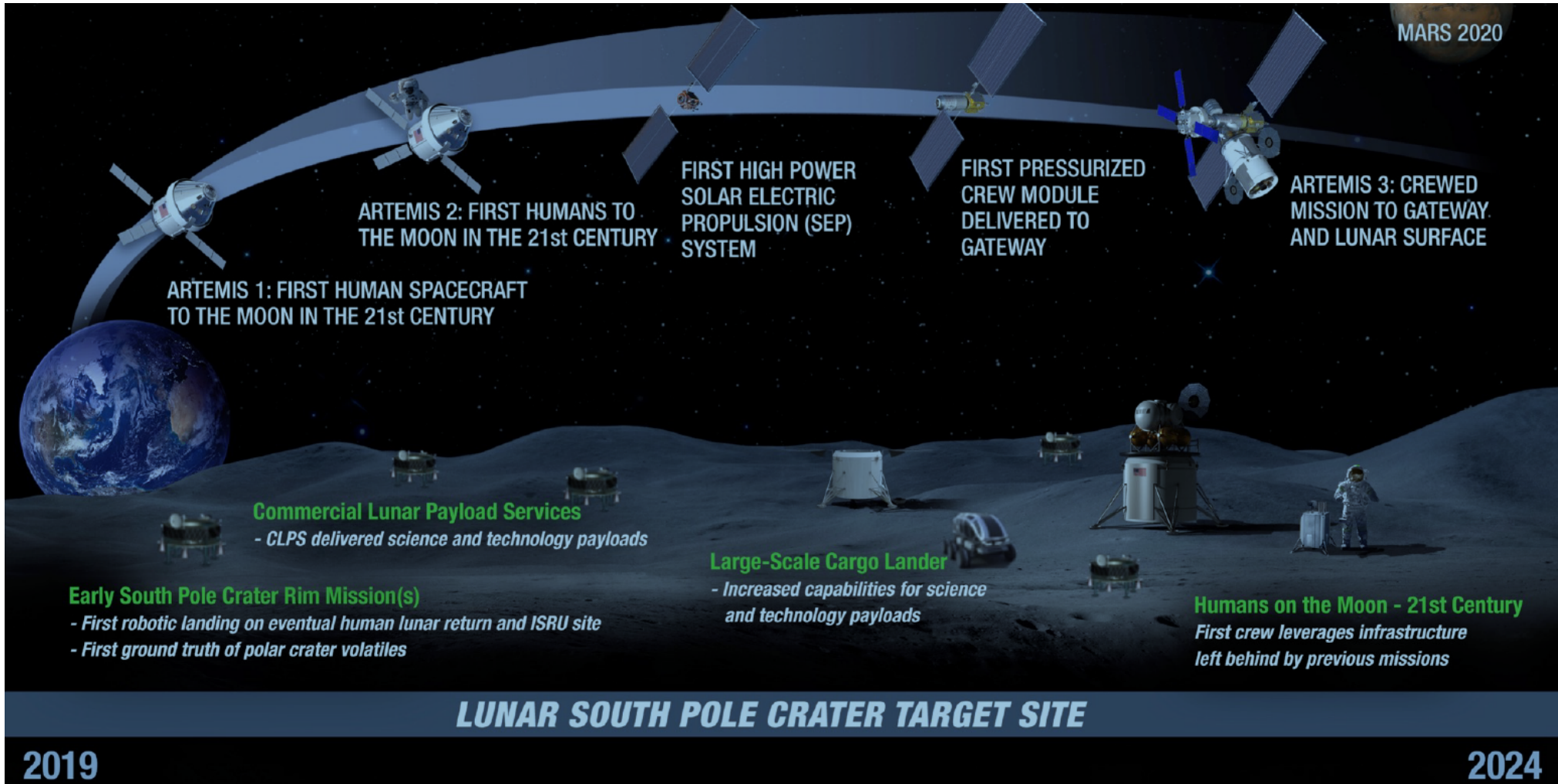


# NASA's Plan: Artemis



*Create and Learn Presentation 2020*







A wide-angle photograph of a NASA Mission Control Room. The room is filled with rows of consoles, each equipped with multiple computer monitors displaying various data, including satellite imagery, orbital paths, and system status. Several people are seated at the consoles, working. The back wall features a large curved wall of screens and is decorated with numerous NASA mission patches. The text "Mission Control and Time Delay" is overlaid in the center of the image.

# Mission Control and Time Delay





## A Brief and Woefully Incomplete History:

- Stage Coach -1860 (weeks)
- Pony Express 1860-1861 (days)
- Telegraph 1861- (minutes)
- Trans-oceanic telegraph 1866
- Telephone 1876 (switchboards 1894)
- Fax 1964
- Electronic Mail (ARPANet) 1971
- Texting (SMS) 1994

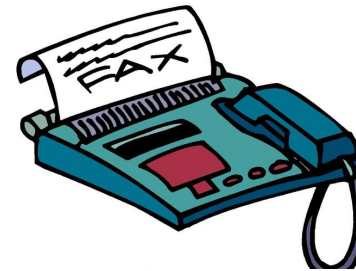
Days



Minutes



Voice,  
Instant  
Print,  
Instant  
Instant





Days



Minutes

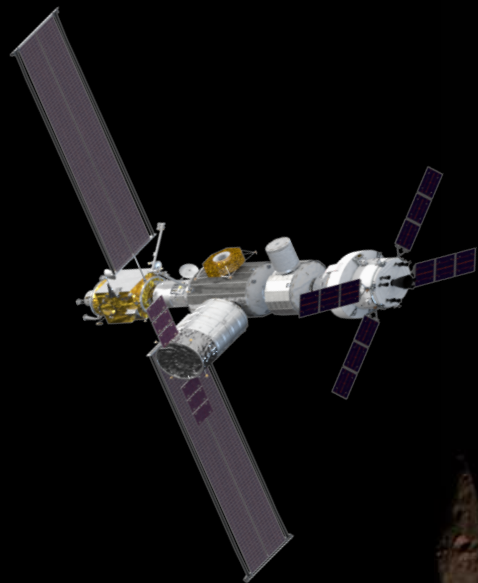
Voice,  
Instant  
Print,  
Instant  
Instant



## Mission Control is:

- The Power Company
- The Plumber
- The A/C Repairman
- The Doctor
- The Phone Company
- Geek Squad
- ...
- Effective Mission Operations requires  
**COMMUNICATION!**





**Phobos, MRO,  
2008.**

**“Houston, we have a  
problem...”**





# Audience Participation Game!



Hello, Artemis, this is  
Mission Control,  
how can I help you?

When was the last  
time you cleaned  
the toilet?

Have there been  
any interruptions  
in power?

Our toilet hasn't  
been working for  
the last day.

We last serviced it  
three weeks ago.

No, the power  
hasn't gone out.

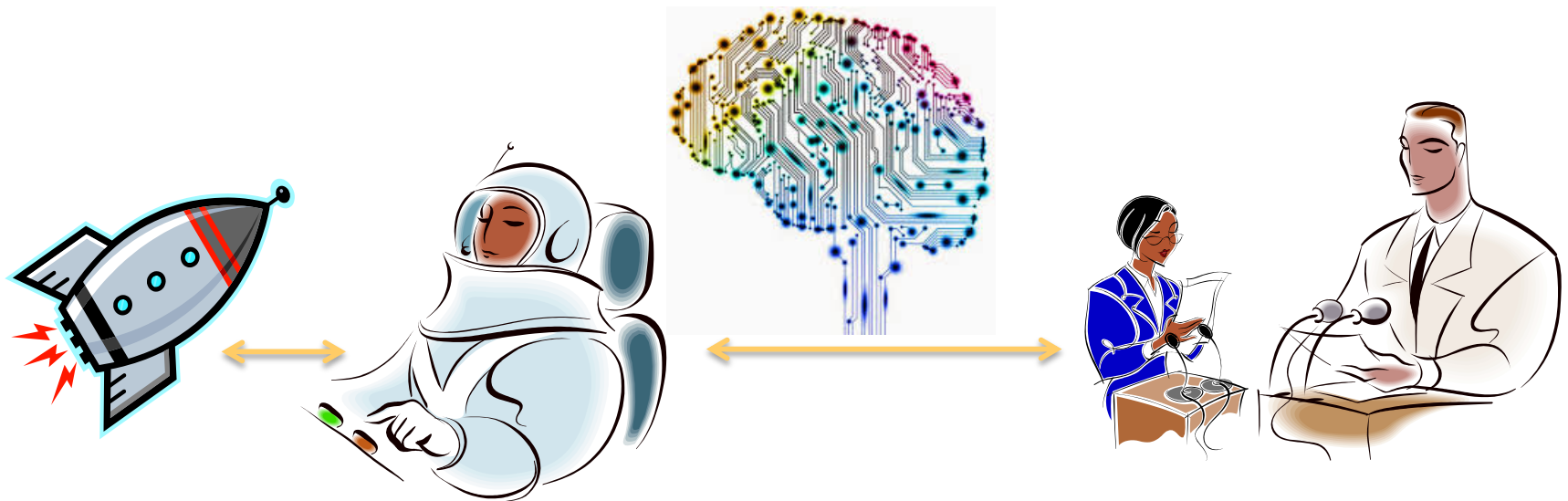
[illegible]



**How do we make the spacecraft smart?**

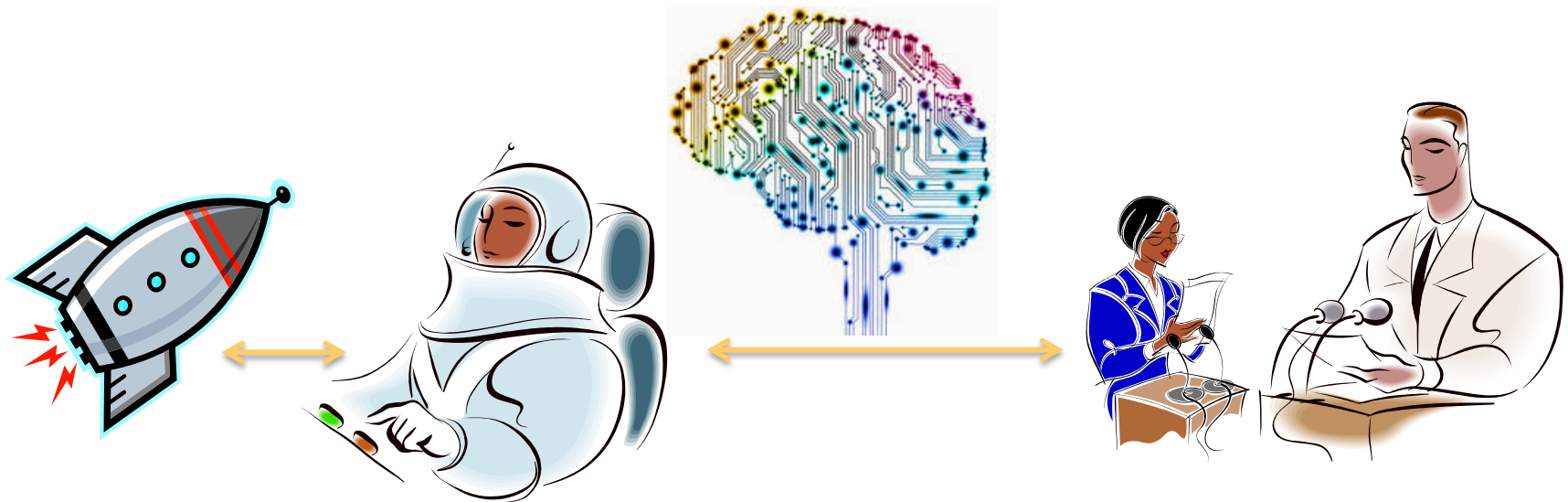
**How do we make the astronauts smarter?**

**Solution: Use Artificial Intelligence!**



## What is AI?

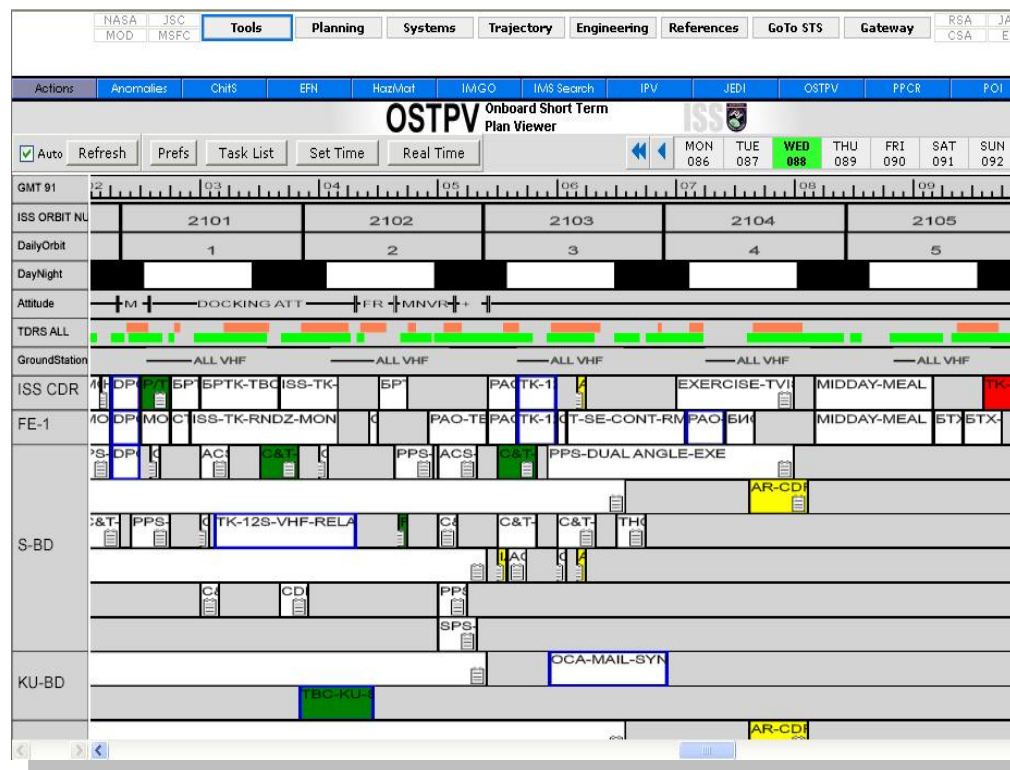
Leading AI textbooks define the field as the study of "intelligent agents": an entity that perceives its environment and takes actions that maximize its chance of successfully achieving its goals.





## Purpose

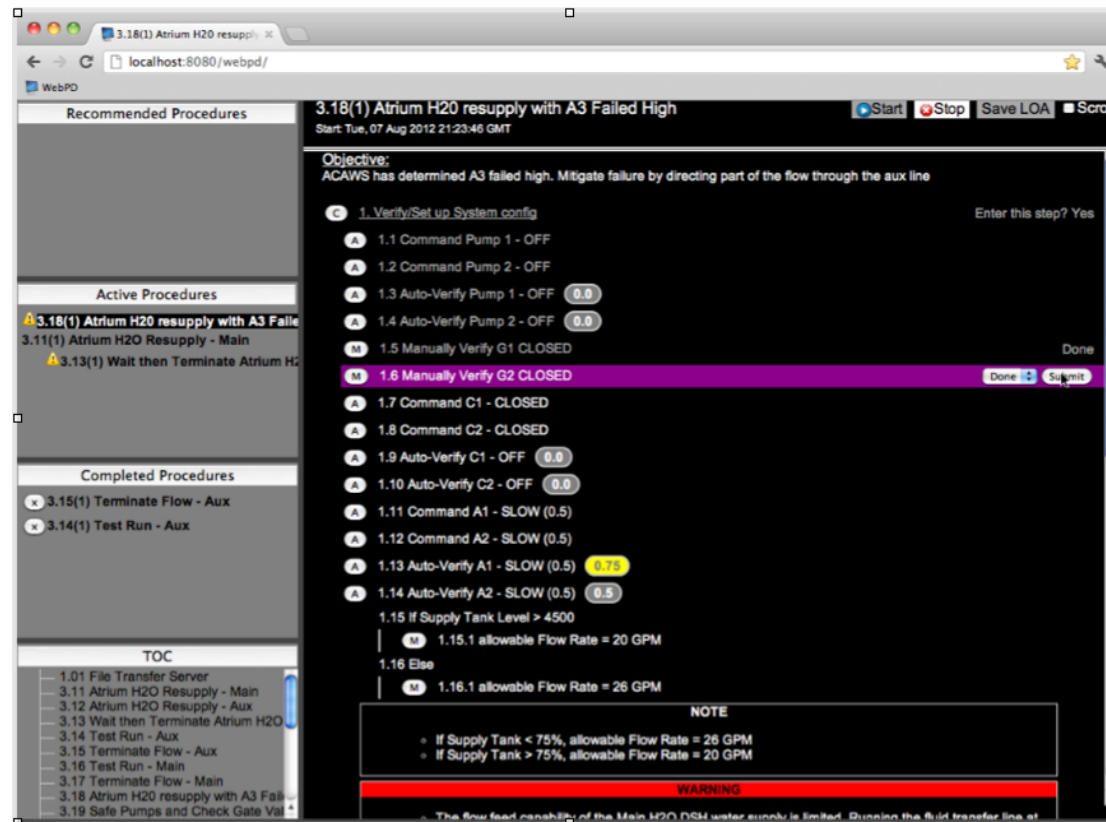
- **Build a plan by choosing activities to achieve goals.**



- **Applications:** Planning astronaut activities, science experiments, equipment maintenance.

## Purpose

- Carry out a plan using an appropriate execution strategy.



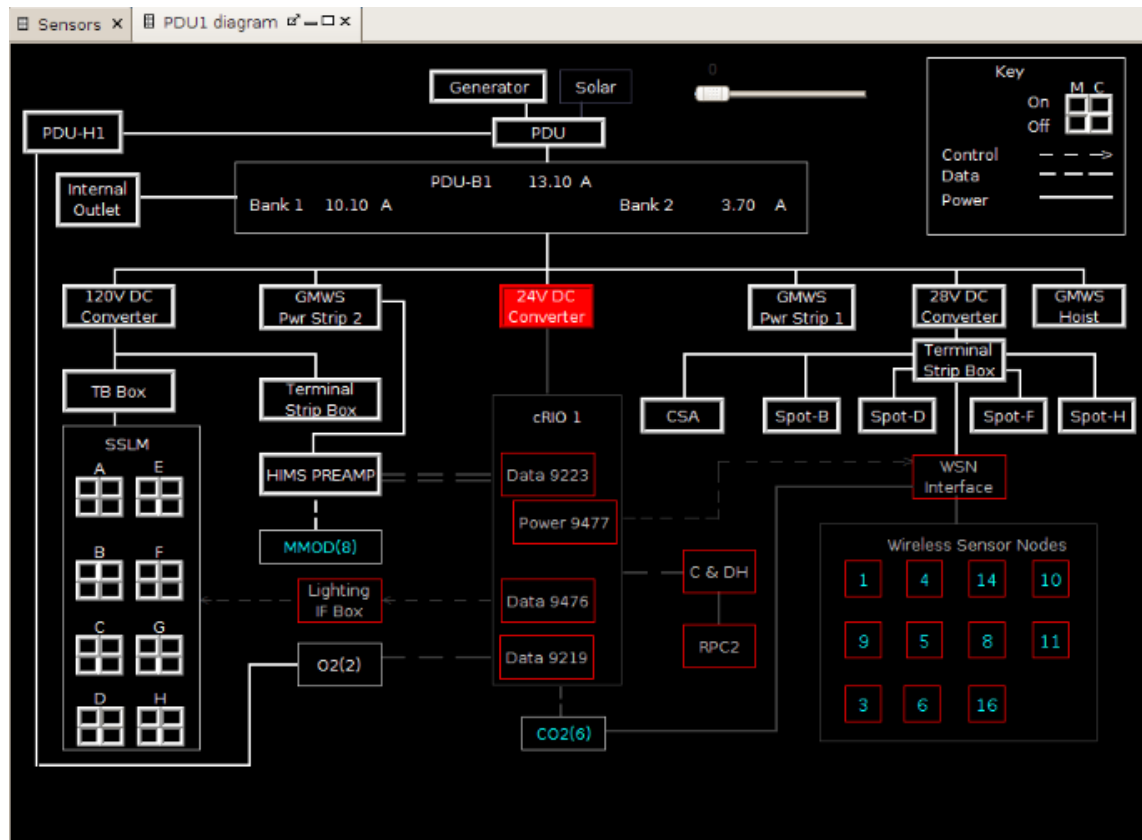
- **Applications:** Automating spacecraft systems, help astronauts perform tasks, automating robots





## Purpose

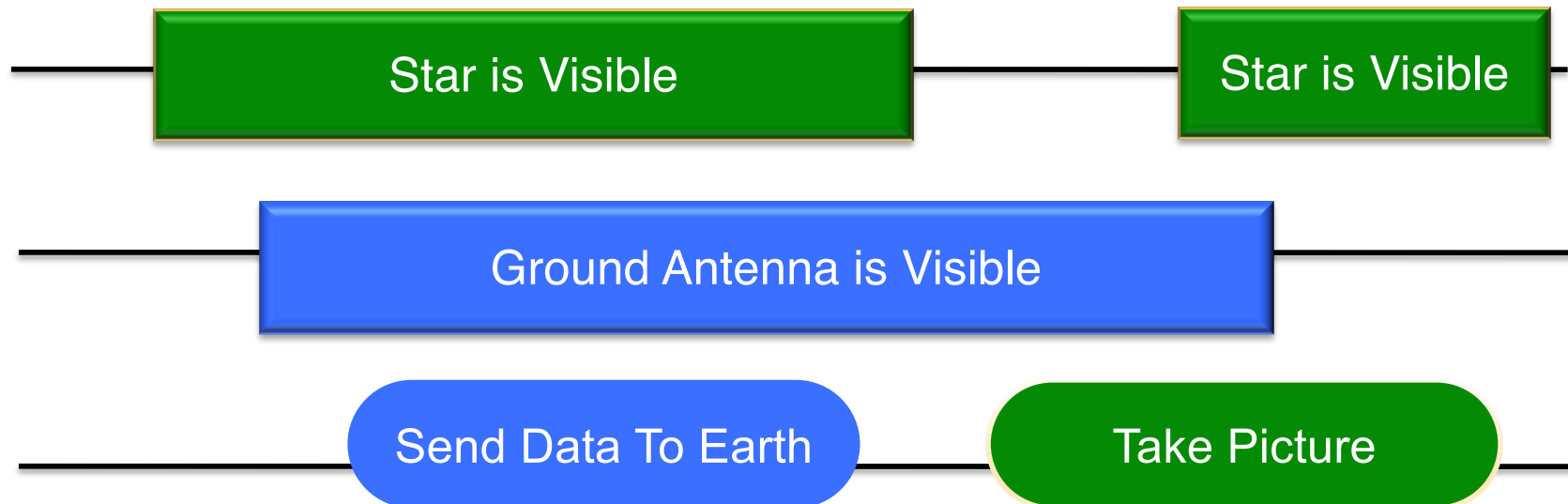
- Monitor system to determine whether **faults** have occurred.
- Determine what faults have taken place.
- Assess remaining system **capability**.



**These AI capabilities use a form of mathematics called Automated Reasoning.**

**Example: How do we schedule activities ‘Take Picture’ and ‘Send Data to Earth’?**

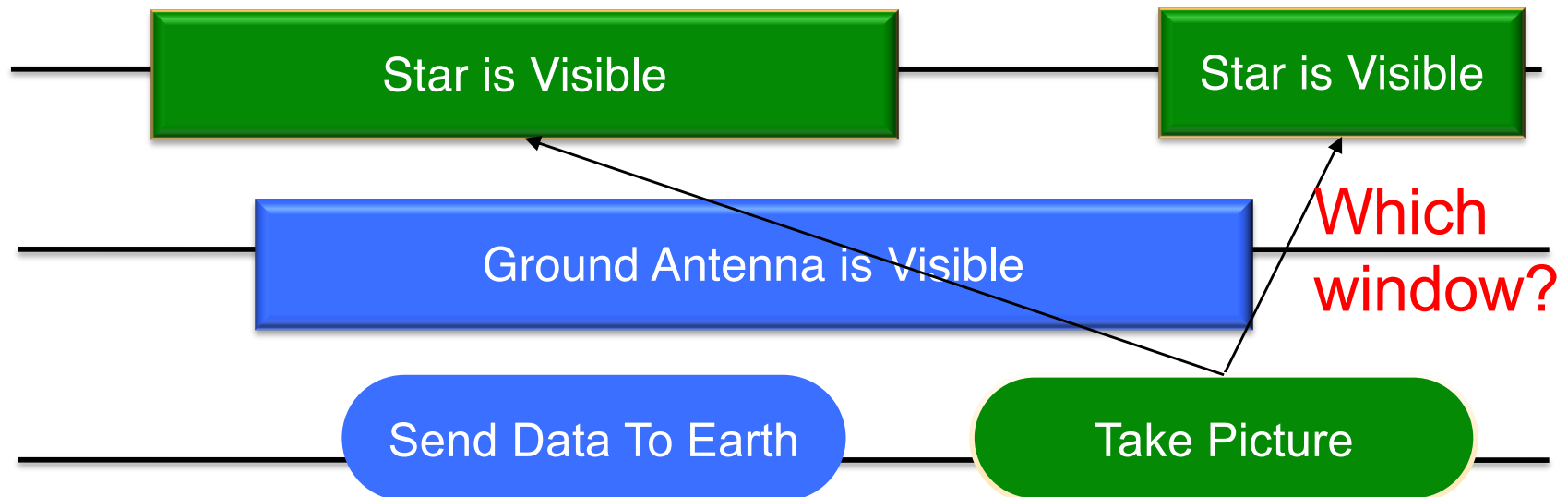
**Each activity must fit in a ‘window’ of the ‘right color’, and they may not overlap.**



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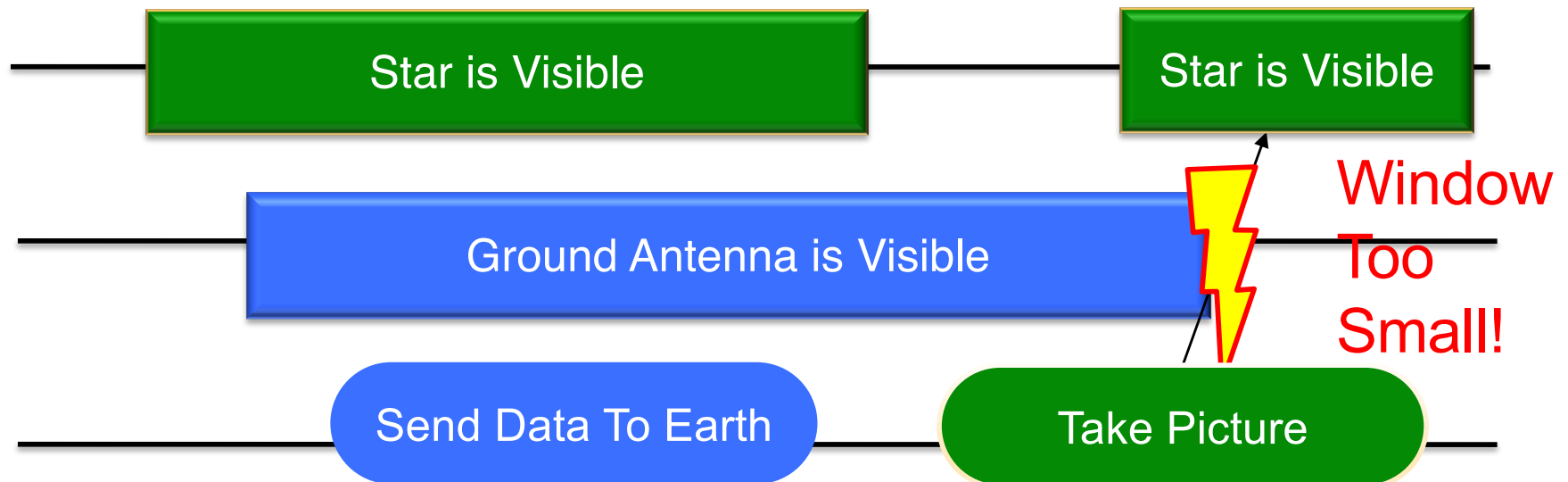




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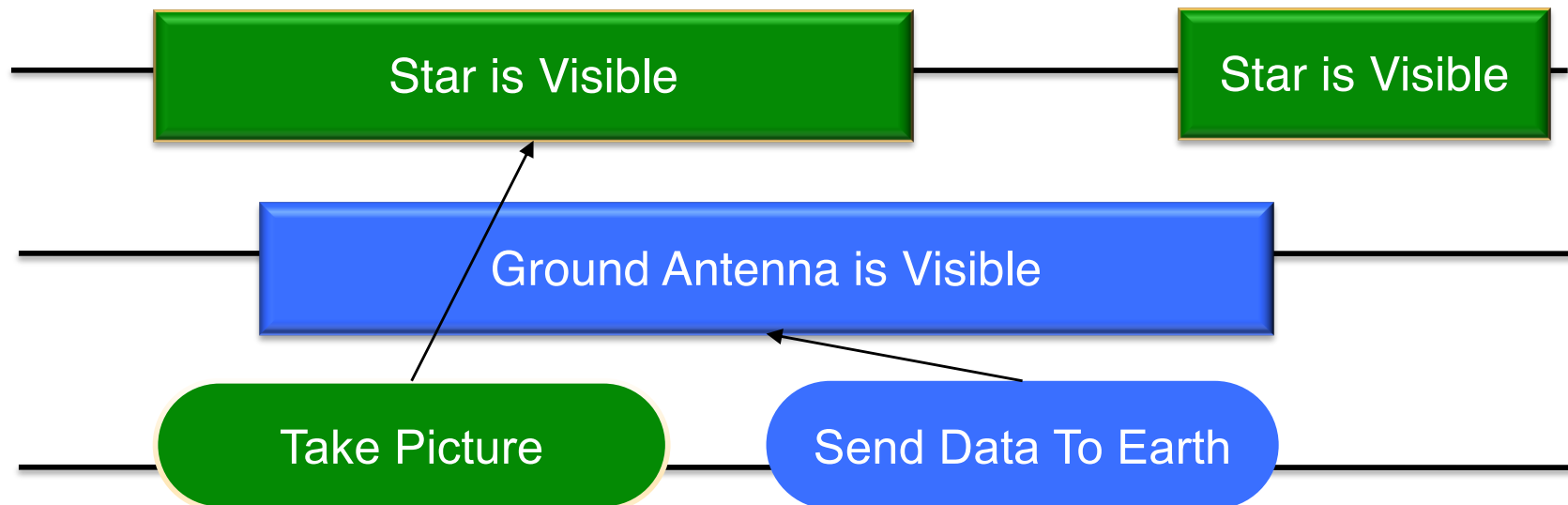
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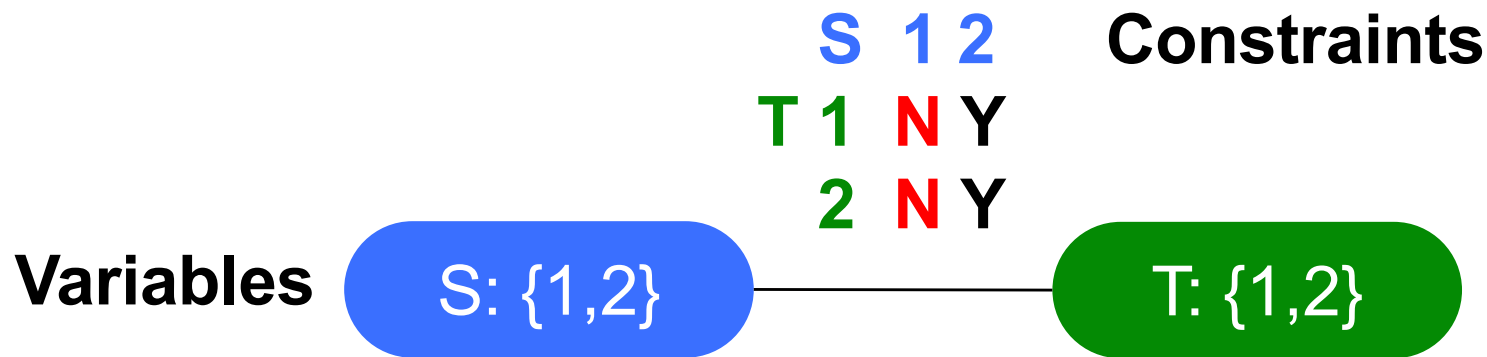
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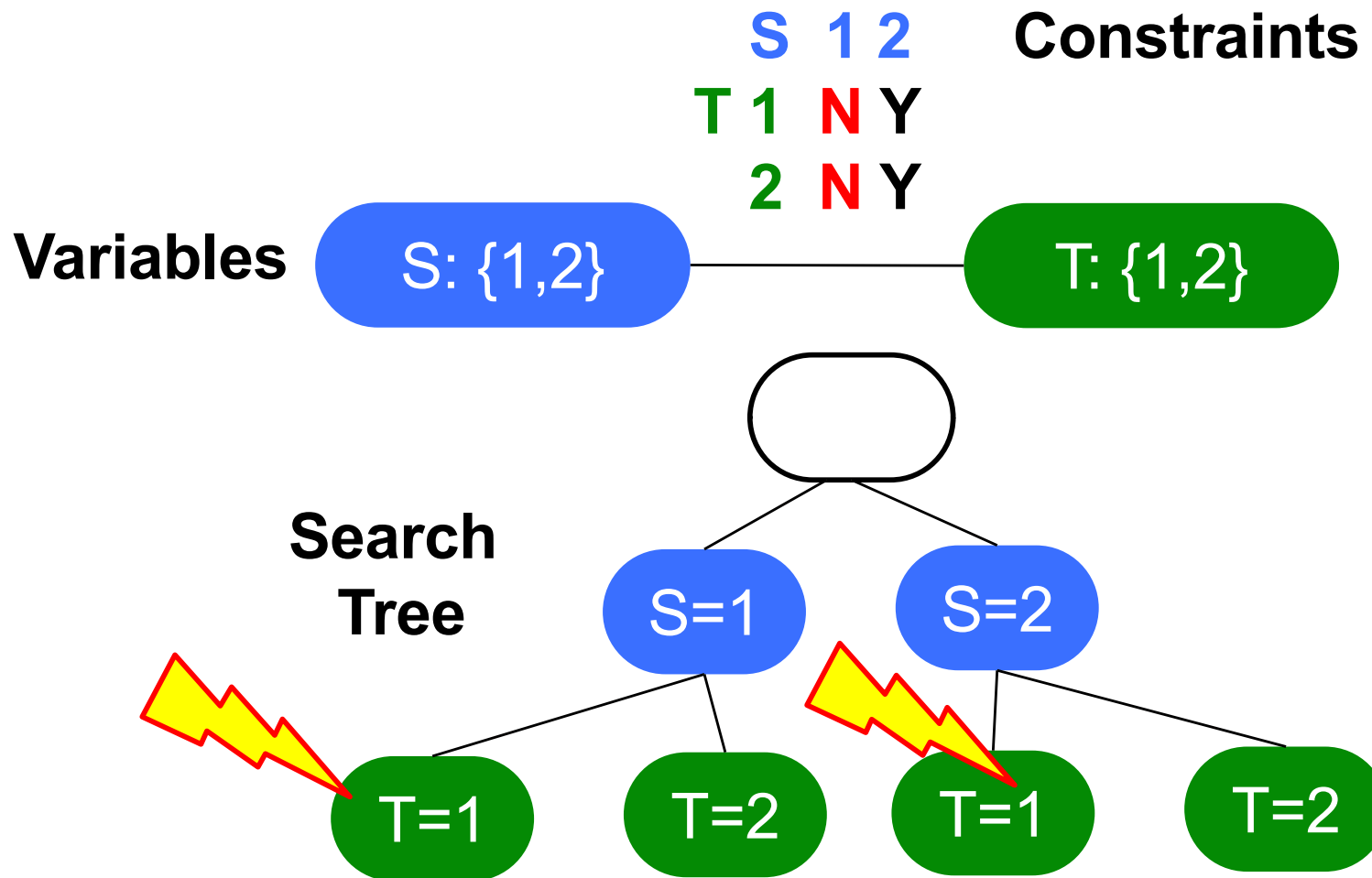


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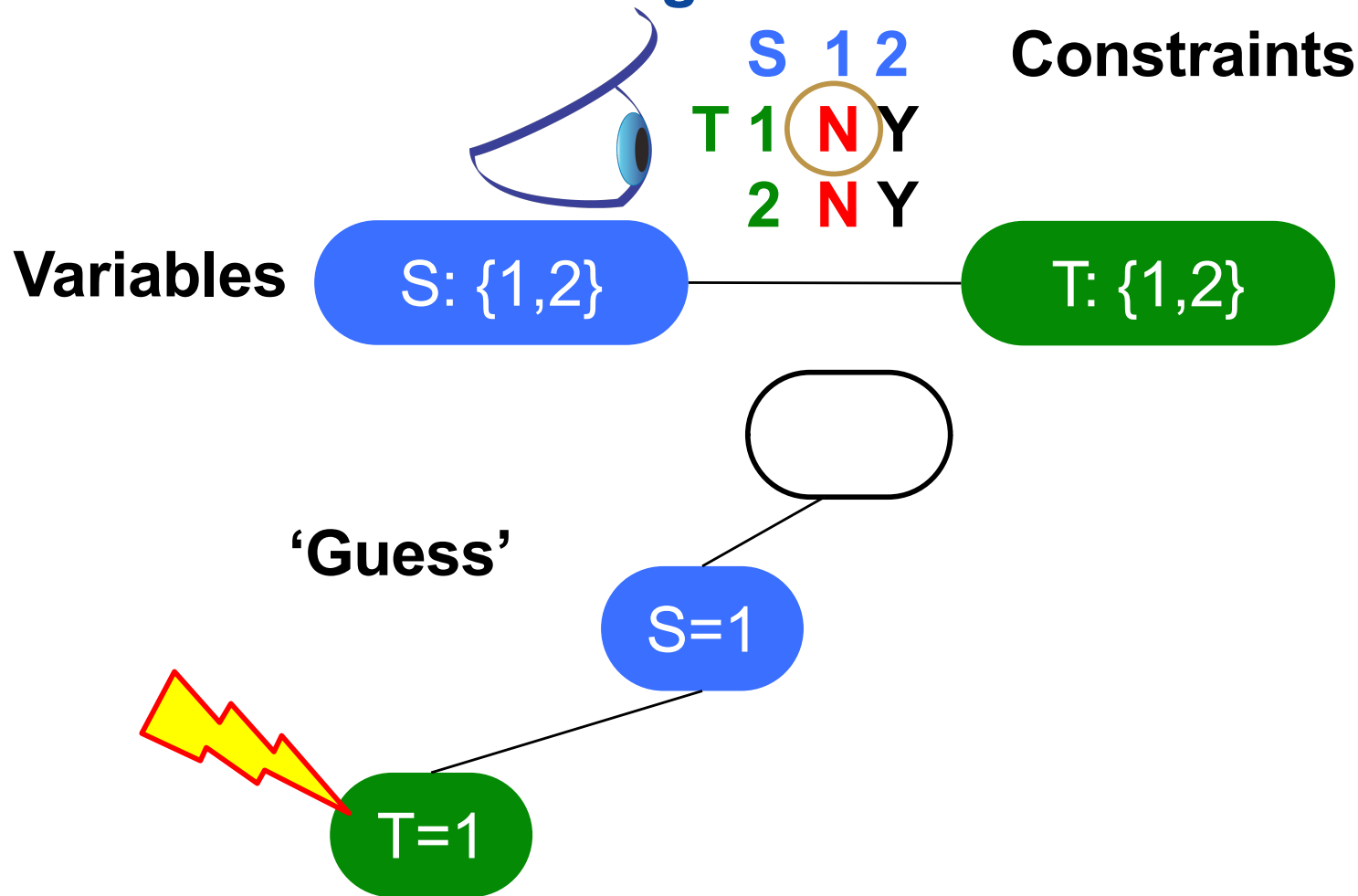




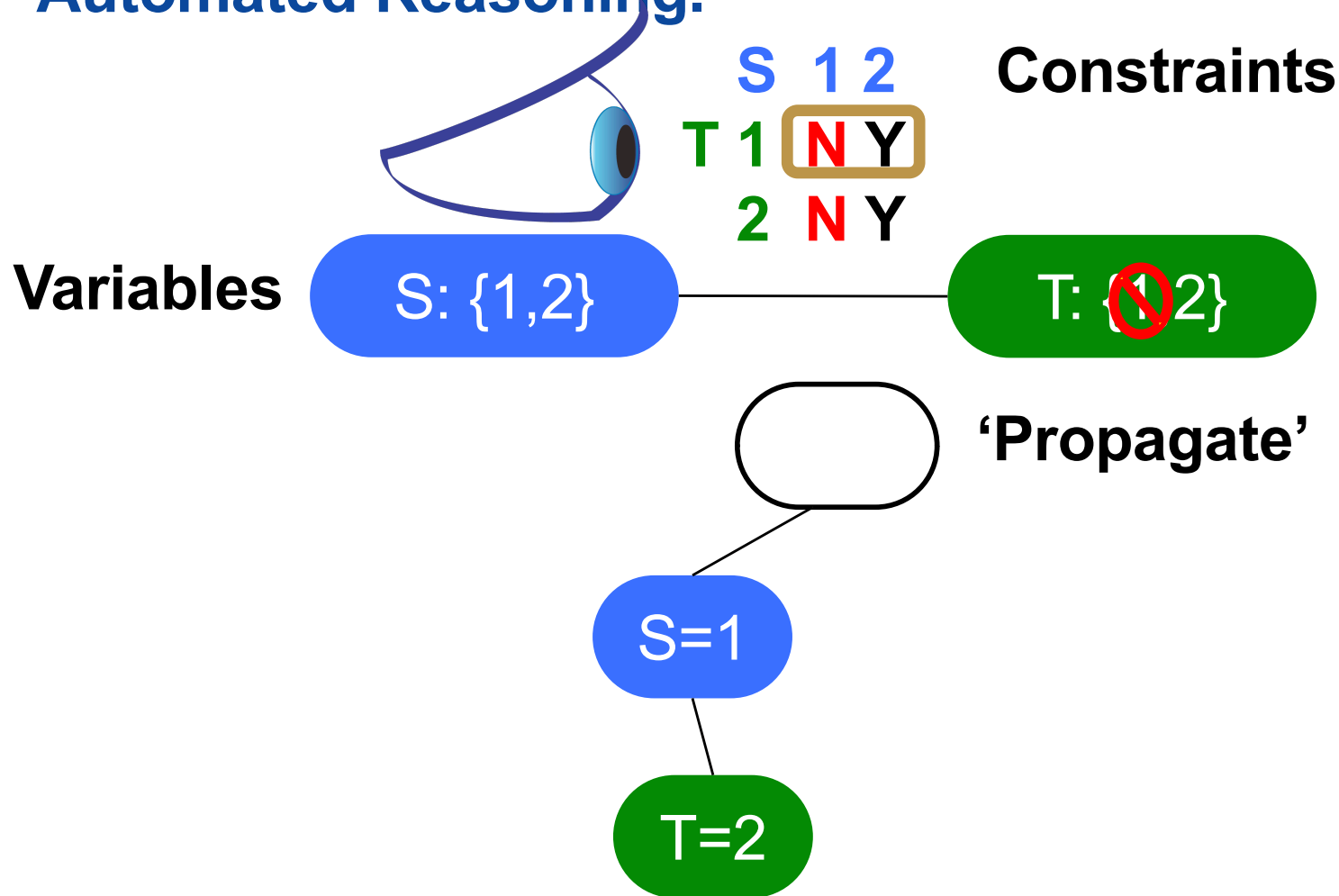
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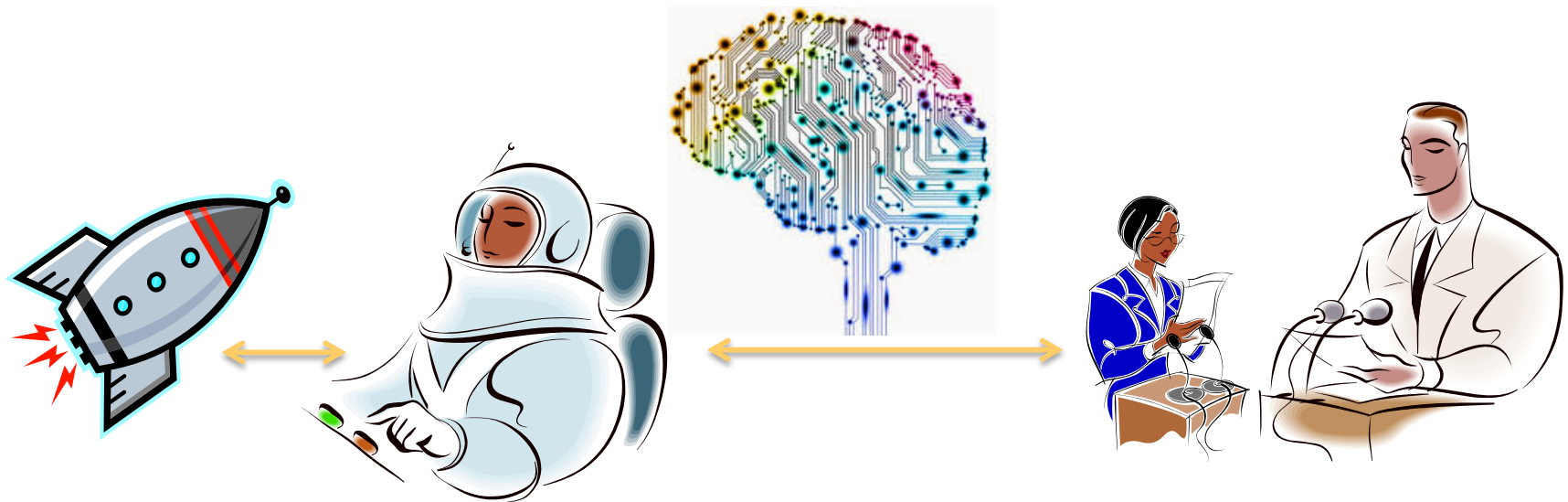
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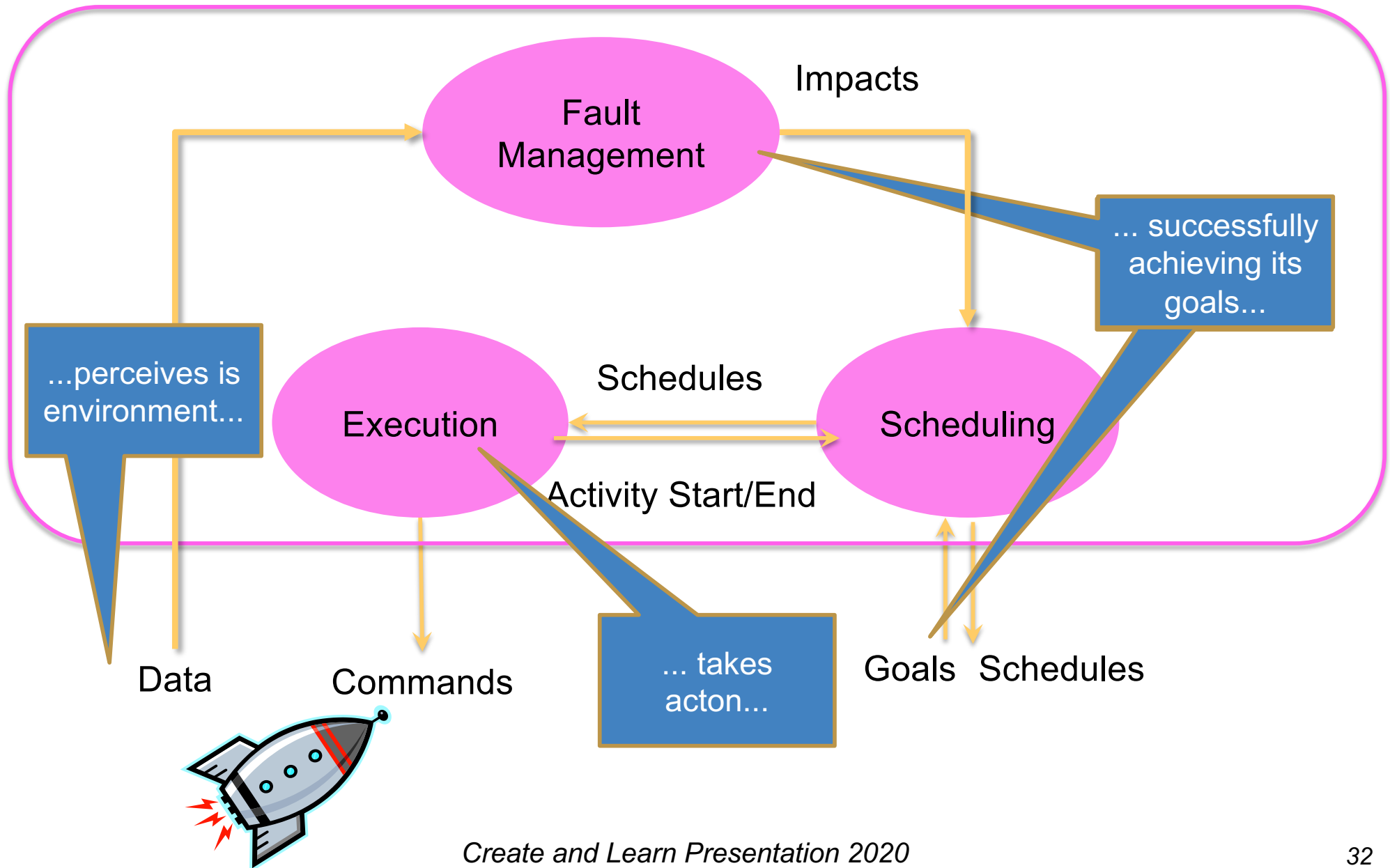




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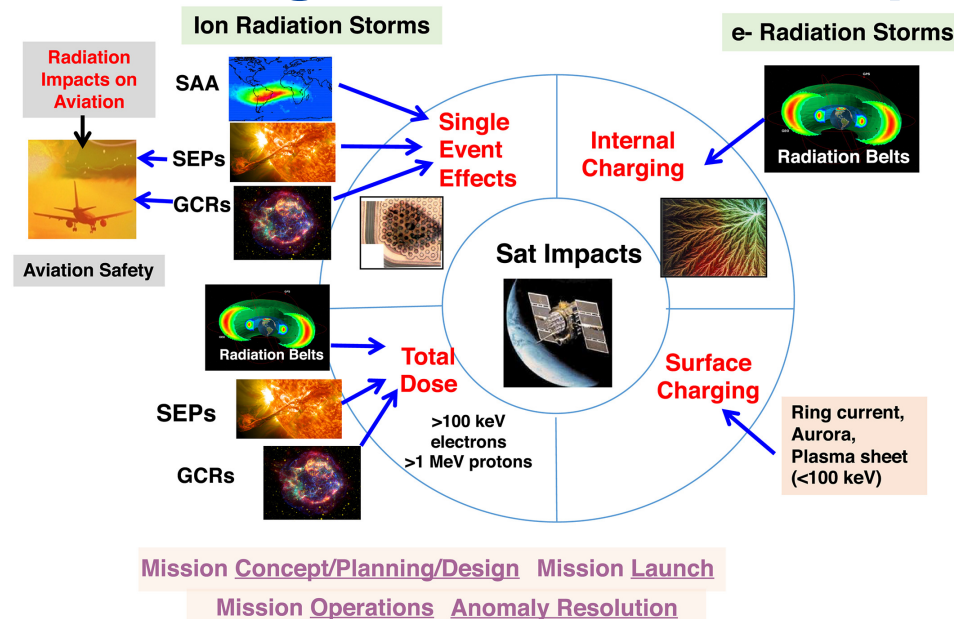


AI software is implemented in many different languages.

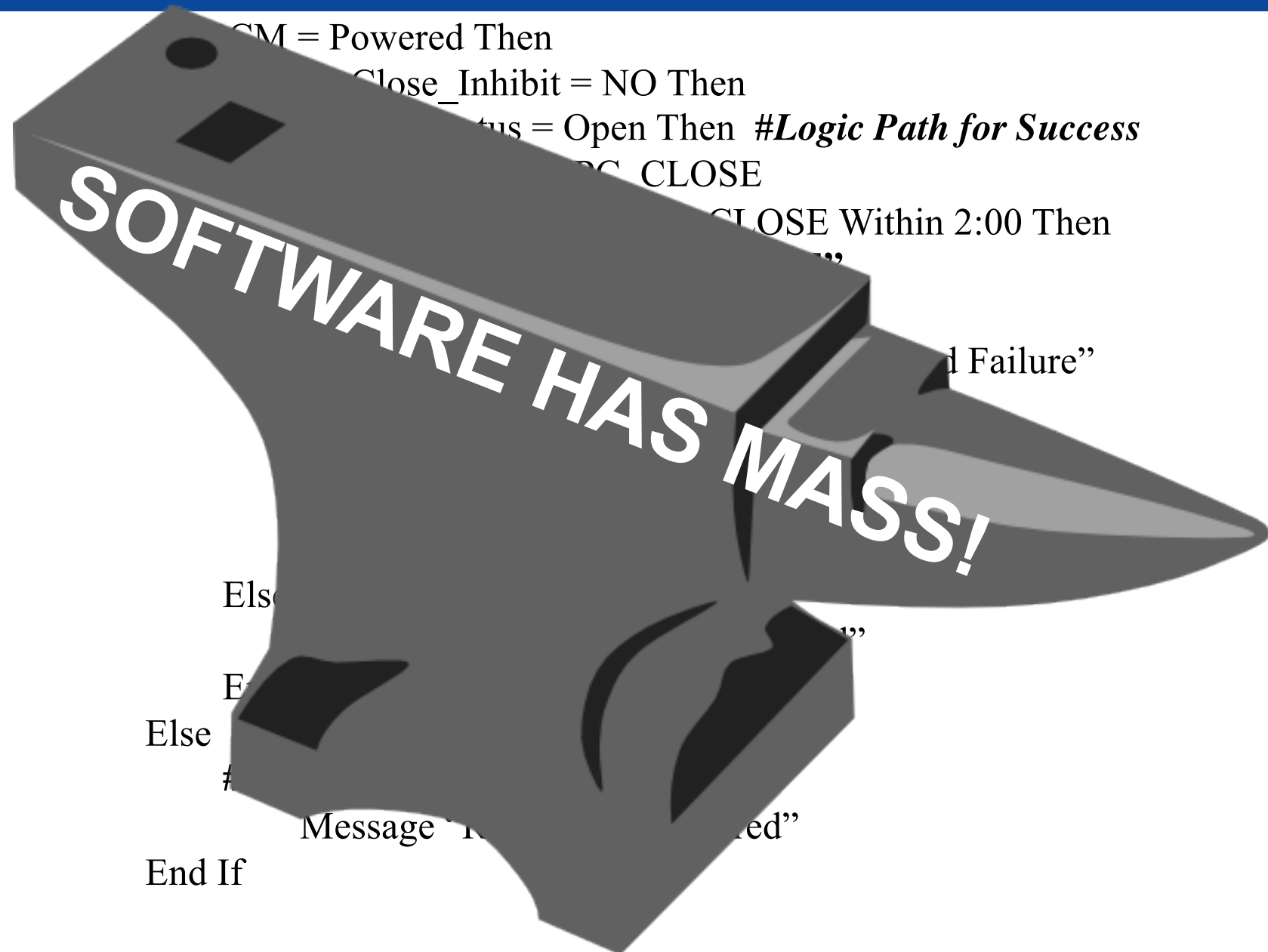
C, C++, Java, Python...etc...

For spaceflight, software must run on special computers.

AI software also requires information from sensors, which imposes design constraints on spacecraft...









Making it Happen!



## Testing Autonomous Habitat Operations



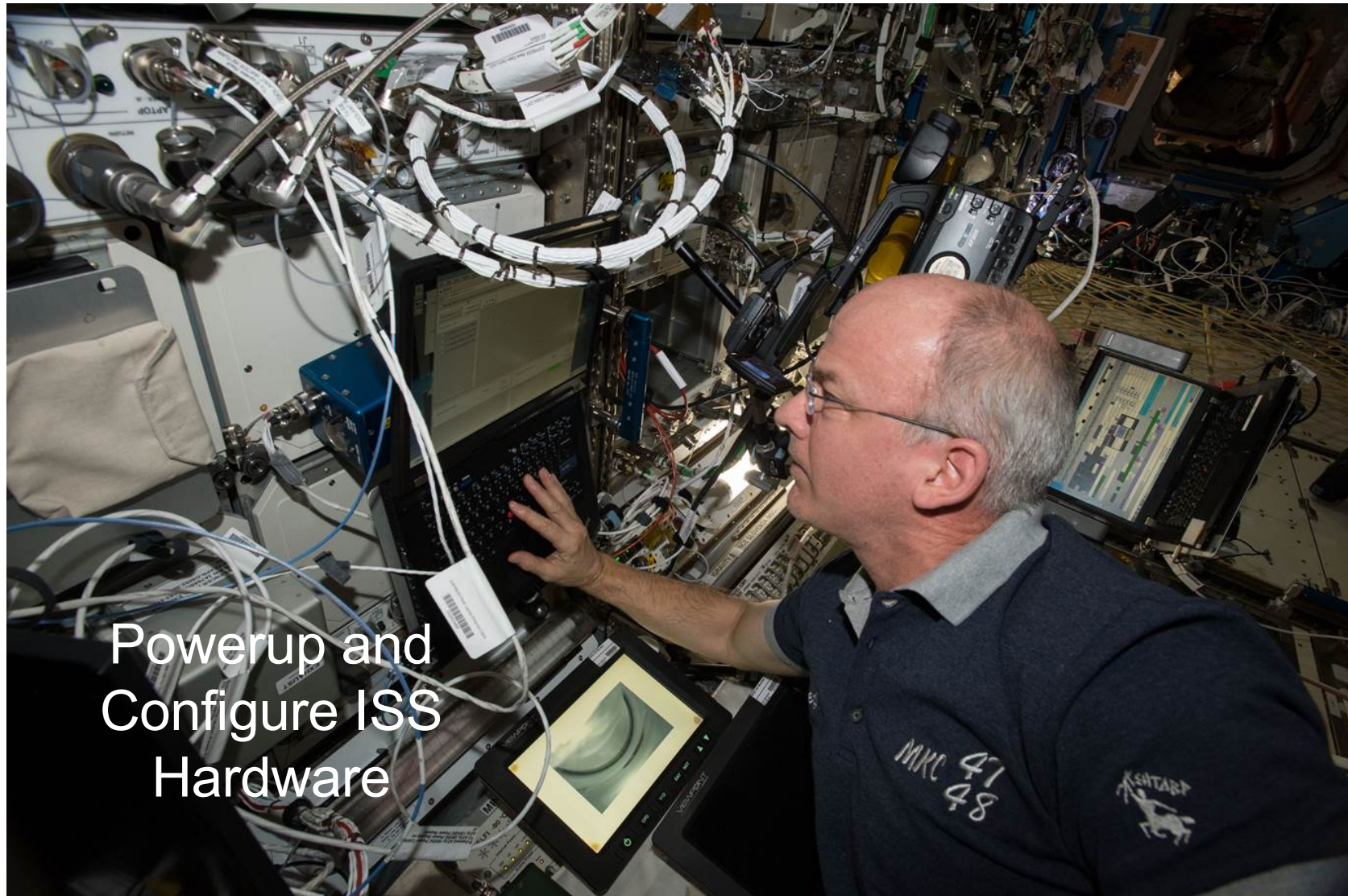


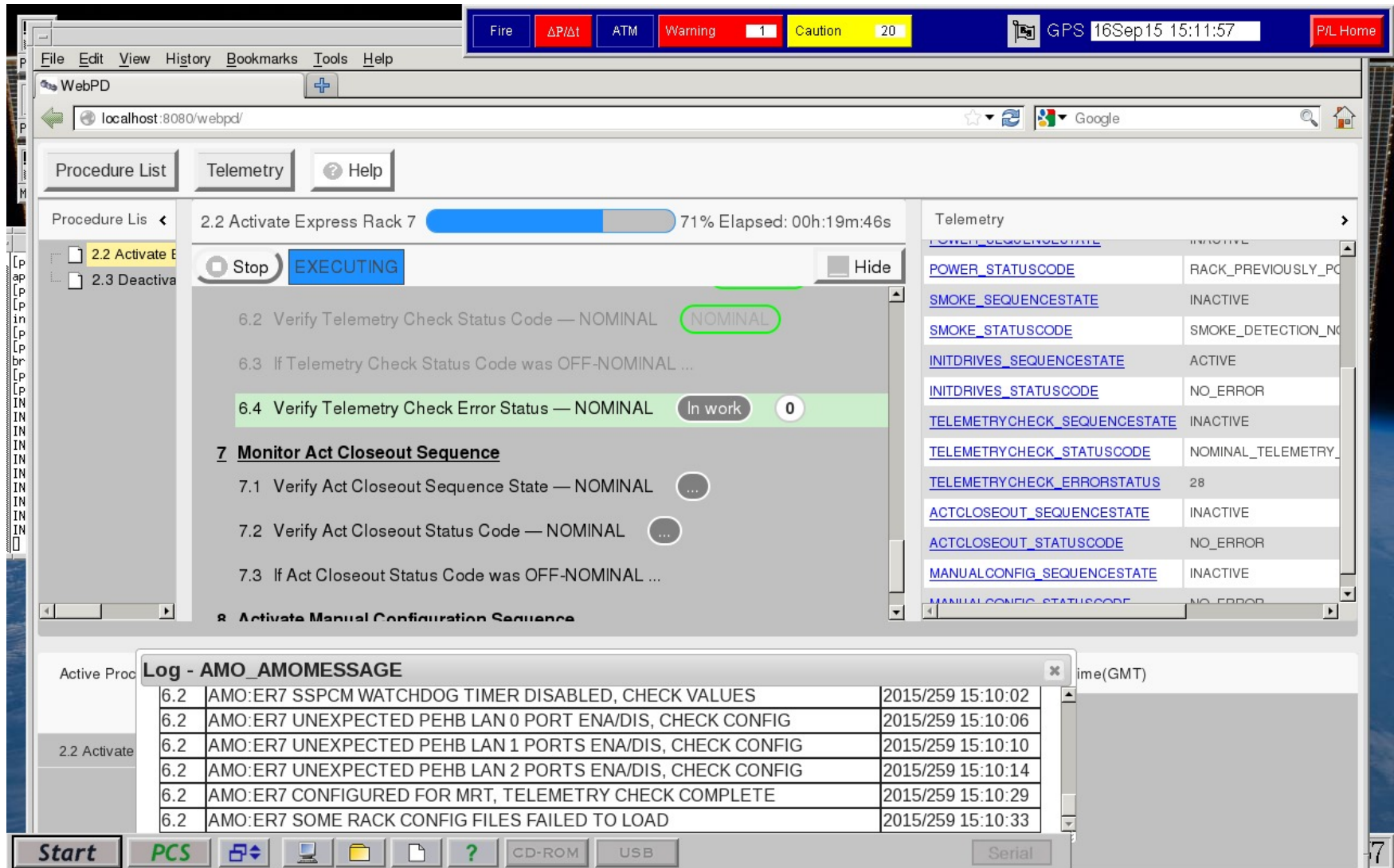












The screenshot displays the Artemis WebPD (Web-based Procedure Display) interface. At the top, a status bar shows various indicators: Fire, ΔP/Δt, ATM, Warning (1), Caution (20), GPS (16Sep15 15:11:57), and P/L Home. The main window is divided into several sections:

- Procedure List:** Shows a list of procedures, with '2.2 Activate Express Rack 7' selected. A progress bar indicates 71% completion, and the elapsed time is 00h:19m:46s.
- Telemetry:** A table of telemetry data is displayed on the right side of the screen.
- Log - AMO\_AMOMESSAGE:** A window at the bottom shows a list of messages, including 'AMO:ER7 SSPCM WATCHDOG TIMER DISABLED, CHECK VALUES' and 'AMO:ER7 UNEXPECTED PEHB LAN 0 PORT ENA/DIS, CHECK CONFIG'.

The interface also includes a 'Start' button, a 'PCS' button, and a 'Serial' button. The bottom right corner shows a '7' icon.

Sequence State	Status
POWER_SEQUENCESTATE	INACTIVE
SMOKE_SEQUENCESTATE	INACTIVE
SMOKE_STATUSCODE	SMOKE_DETECTION_NO
INITDRIVES_SEQUENCESTATE	ACTIVE
INITDRIVES_STATUSCODE	NO_ERROR
TELEMETRYCHECK_SEQUENCESTATE	INACTIVE
TELEMETRYCHECK_STATUSCODE	NOMINAL_TELEMETRY
TELEMETRYCHECK_ERRORSTATUS	28
ACTCLOSEOUT_SEQUENCESTATE	INACTIVE
ACTCLOSEOUT_STATUSCODE	NO_ERROR
MANUALCONFIG_SEQUENCESTATE	INACTIVE
MANUALCONFIG_STATUSCODE	NO_ERROR

Message	Time (GMT)
6.2 AMO:ER7 SSPCM WATCHDOG TIMER DISABLED, CHECK VALUES	2015/259 15:10:02
6.2 AMO:ER7 UNEXPECTED PEHB LAN 0 PORT ENA/DIS, CHECK CONFIG	2015/259 15:10:06
6.2 AMO:ER7 UNEXPECTED PEHB LAN 1 PORTS ENA/DIS, CHECK CONFIG	2015/259 15:10:10
6.2 AMO:ER7 UNEXPECTED PEHB LAN 2 PORTS ENA/DIS, CHECK CONFIG	2015/259 15:10:14
6.2 AMO:ER7 CONFIGURED FOR MRT, TELEMETRY CHECK COMPLETE	2015/259 15:10:29
6.2 AMO:ER7 SOME RACK CONFIG FILES FAILED TO LOAD	2015/259 15:10:33



## Crew Management of Water Quality Sampling



Status	Procedure	Rationale
<b>This Week (GMT 2014/342 - 2014/348)</b>		
Requested	<a href="#">ISTAR Total Organic Carbon Analyzer: TOCA - Waste Water Bag Changeout (Med Ops 6.3.350)</a>	Required every 6 runs and prior to next run
Scheduled	<a href="#">ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis Using TOCA Water Sample Hose (Med Ops 6.3.250)</a>	Required weekly
<b>Next Week (GMT 2014/349 - 2014/355)</b>		
Requested	<a href="#">ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis Using TOCA Water Sample Hose (Med Ops 6.3.250)</a>	Required weekly
<b>Future Week (GMT 2014/356 - 2014/362)</b>		
Recommended	<a href="#">ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis Using TOCA Water Sample Hose (Med Ops 6.3.250)</a>	Required weekly
Recommended	<a href="#">ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis From TOCA Sample Analysis Bag (Med Ops 6.3.300) (for Hot PWD)</a>	Required monthly (alternating between the hot and ambient ports)



# Testing onboard the ISS

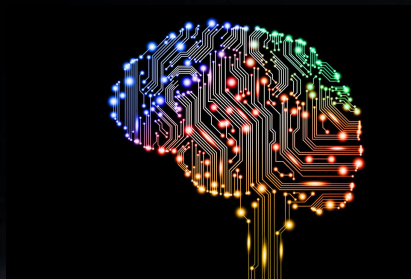


**NASA investments in AI technology will augment crew expertise and knowledge, reduce crew workload, and enable efficient dormant operations.**

**These investments will, ultimately, pave the way for future human exploration of the Solar system.**



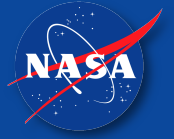
*Significant challenges remain!*



*So Let's Keep Working it!*



# More Resources!



## **Learn More About Artemis!**

<https://www.nasa.gov/stem/artemis.html>

## **Artemis Hour of Code Challenges!**

<https://www.tynker.com/hour-of-code/nasa-moon-2-mars>

## **NASA K-12 Educator Resources!**

<https://www.nasa.gov/aeroresearch/resources/k-12>